APPENDIX I. ENVIRONMENTAL CONSEQUENCES OF LONG-TERM REPOSITORY PERFORMANCE

This appendix provides detailed supporting information on the calculation of the environmental consequences of long-term repository performance (postclosure, up to 1 million years). Chapter 5 summarizes these consequences for the Proposed Action, and Chapter 8, Section 8.3.1 summarizes the cumulative impacts of Inventory Modules 1 and 2.

Section I.1 introduces the bases for analysis of long-term performance. Section I.2 provides an overview of the use of computational models developed for the Total System Performance Assessment (TSPA) model, that was used for the analysis of long-term impacts to groundwater in this environmental impact statement (EIS). Section I.3 identifies and quantifies the inventory of waste constituents of concern for analysis of long-term performance. Section I.4 details the modeling extensions to the TSPA *nominal scenario* [Proposed Action inventory, reasonably maximally exposed individual (RMEI) location at approximately 18 kilometers, or 11 miles, downgradient of the potential repository, and no disruptive events other than seismic] developed to estimate potential impacts for expanded inventories. An estimate of how the impacts might change for locations beyond the RMEI location is also provided. Section I.5 provides detailed results for waterborne radioactive material impacts, while Section I.6 provides the same for waterborne chemically toxic material impacts. Section I.7 describes atmospheric radioactive material impacts. To aid readability, all the figures are placed at the end of the appendix.

HOW ARE THE TOTAL SYSTEM PERFORMANCE ASSESSMENT MODEL AND THIS EIS ANALYSIS RELATED?

The analysis of long-term performance for this EIS builds incrementally on the TSPA model.

This appendix is primarily concerned with those aspects of the EIS analysis of long-term performance that are incremental over the TSPA model. Only those parts of the analysis unique to this EIS are detailed in this appendix, and the text refers to the appropriate TSPA model documents for information on the bases of the analyses. Some aspects of the modeling detailed in the TSPA are repeated in this appendix in overview form to provide continuity and enhance understanding of the approach.

For a full understanding of all details of the analysis of long-term performance in this EIS, it is necessary to study not only this appendix but also the other TSPA model documents cited herein.

I.1 Introduction

This EIS analysis of postclosure impacts used and extended the modeling work performed for the Yucca Mountain site suitability evaluation that supports the site recommendation process. The EIS analysis relied on the GoldSim program computer simulation model (DIRS 151202-Golder Associates 2000, all) used by DOE to calculate radiological doses resulting from waterborne releases through the groundwater pathway.

Analysis of long-term performance for this EIS required several steps. The EIS analysis model started with the TSPA model, which was modified as discussed below. For this EIS the modeling (described in this appendix) was further expanded to evaluate the impacts for expanded waste inventories (see Section I.4). Additional calculations provided estimates of how the impacts would vary for two other distances [30 kilometers (19 miles) downgradient, and the discharge location that is 60 kilometers (37 miles) downgradient at Franklin Lake Playa (refer to Section I.4.5)], analysis of long-term groundwater impacts of chemically toxic materials, and estimates of atmospheric radiological doses to the local population.

The model used to evaluate long-term impacts of radioactive materials in the groundwater simulates the release and transport of radionuclides away from the repository into the unsaturated zone, through the unsaturated zone, and ultimately through the saturated zone to the accessible environment. Analysis of long-term performance depends greatly on the underlying process models necessary to provide thermal-hydrologic conditions, near-field geochemical conditions, unsaturated zone flow fields, and saturated zone flow fields as a function of time. Using these underlying process models involves multiple steps that must be performed sequentially before modeling of the overall system can begin.

Figure I-1 shows the general flow of information between data sources, process models, and the TSPA model. Several process-level computer models are identified in Figure I-1. Examples are the site- and drift-scale thermal hydrology model and the saturated zone flow and transport model. The process models are very large and complex computer software programs used in detailed studies to provide information to the TSPA model. These process models are generally where fundamental laboratory and field data are introduced into the modeling. The subsystem and abstracted models section of the figure encompasses those portions of the TSPA model that are modeled within the GoldSim program. Examples are the unsaturated zone flow fields and the biosphere dose conversion factors. These models are generally much simpler than the process models. They are constructed to represent the results of the more detailed process modeling studies. Often they are simple functions or tables of numbers. This is the process referred to as *abstraction*. It is necessary for some of these subsystem models to be quite complex, even extensive computer codes. The ultimate result sought from modeling long-term performance is a characterization of radiological dose to humans with respect to time, shown at the top of the TSPA section of the figure. This is accomplished by assessing behavior at intermediate points and "handing" off the results to the next subsystem in the primary release path.

ABSTRACTION

Abstraction is the distillation of the essential components of a process model into a suitable form for use in a TSPA. The distillation must retain the basic intrinsic form of the process model but does not usually require its original complexity. Model abstraction is usually necessary to maximize the use of limited computational resources while allowing a sufficient range of sensitivity and uncertainty analyses.

I.2 Total System Performance Assessment Methods and Models

DOE conducted analyses for this EIS to evaluate potential long-term impacts to human health from the release of radioactive materials from the Yucca Mountain Repository. The analyses were conducted in parallel with, but distinct from, the TSPA calculations for the site suitability evaluation. The methodologies and assumptions are detailed in the *Total System Performance Assessment for the Site Recommendation* (DIRS 153246-CRWMS M&O 2000, all), and the *FY01 Supplemental Science and Performance Analyses* (DIRS 155950-CRWMS M&O 2001, all). These two versions of the model are referred to respectively here as the "Site Recommendation model" and the "Supplemental Science and Performance Analyses model." Note that the Supplemental Science and Performance Analyses model starts with the Site Recommendation model and includes incremental enhancements to several parts of the Site Recommendation model. Further changes were made to the model to meet distinct requirements of this EIS. These changes are discussed in more detail in Section I.4 and in DIRS 157307-BSC (2001, Enclosure 1). In summary, the changes are as follows:

- The biosphere dose conversion factors are based on the Reasonably Maximally Exposed Individual (RMEI) defined in 40 CFR 197.21.